

Rec'd PCT/PTO 11 JAN 2005

PCT/GB 2003 / 0 0 2 8 3 9



10/520960



INVESTOR IN PEOPLE

**PRIORITY
DOCUMENT**

SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH RULE 17.1(a) OR (b)

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

REC'D 03 OCT 2003

WIPO

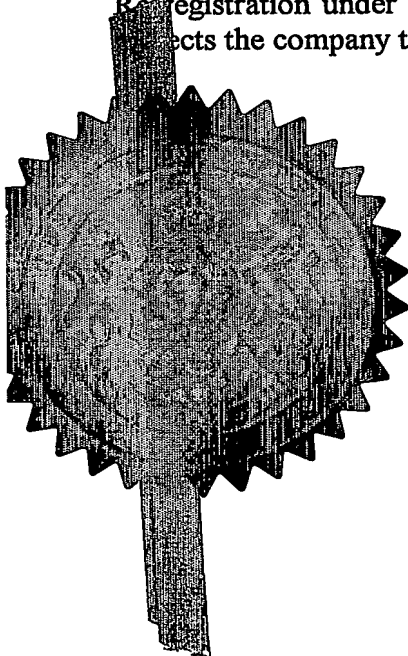
PC

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

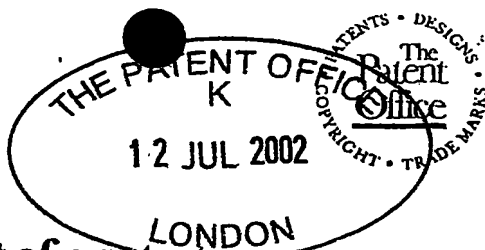
Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.



Signed

Dated 26 August 2003

BEST AVAILABLE COPY



15 JUL 02 E733112-1 010096
P01/7700 0:00-0216259.2

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
South Wales
NP10 8QQ

1. Your reference

P60371GB

2. Patent application number

(The Patent Office will fill in this part)

12 JUL 2002

0216259.2

3. Full name, address and postcode of the or of each applicant (underline all surnames)

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

Sensor Highway Limited
Gamma House
Enterprise Road
Chilworth Science Park
Southampton
Hampshire SO16 7NS

ENGLAND and WALES

8423808001

4. Title of the invention

SUBSEA AND LANDING STRING DISTRIBUTED SENSOR SYSTEM

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

Parabola
1 Richfield Place
Richfield Avenue
Reading
Berkshire RG1 8EQ

Patents ADP number (if you know it)

08236465001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

Country

Priority application number
(if you know it)

Date of filing
(day / month / year)

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

Date of filing
(day / month / year)

Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:

Yes

a) any applicant named in part 3 is not an inventor, or

b) there is an inventor who is not named as an applicant, or

c) any named applicant is a corporate body.

See note (d))

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form

Description	19 ✓
Claim(s)	8 ✓
Abstract	1 ✓

Drawing(s) 5 + 5 20

10. If you are also filing any of the following, state how many against each item.

Priority documents

Translations of priority documents

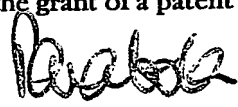
Statement of inventorship and right to grant of a patent (Patents Form 7/77)

Request for preliminary examination and search (Patents Form 9/77)

Yes ✓

Request for substantive examination (Patents Form 10/77)

Any other documents (please specify)

11. I/We request the grant of a patent on the basis of this application.
- | | | |
|-----------|--|-------------|
| Signature |  | Date |
| PARABOLA | | 12 JULY '02 |
12. Name and daytime telephone number of person to contact in the United Kingdom
- | | |
|------------|---------------|
| Paul Wolff | 0118 950 9937 |
|------------|---------------|

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

- If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.
- Write your answers in capital letters using black ink or you may type them.
- If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.
- If you have answered 'Yes' Patents Form 7/77 will need to be filed.
- Once you have filled in the form you must remember to sign and date it.

DUPLICATE

(101.0005)

SUBSEA AND LANDING STRING DISTRIBUTED SENSOR SYSTEM

BACKGROUND

The invention generally relates to the monitoring of parameters, particularly but not exclusively temperature, in the subsea environment and along (either interior or exterior to) a relevant temporary landing string or riser assembly.

5 At various times during the life of a subsea well, a temporary marine riser is located between a blow out preventer (BOP) and a platform at the ocean surface. The BOP is located at the ocean bottom. In instances when a vertical christmas tree will be used, a BOP is installed for the drilling and completion stages of the well. Thereafter, the BOP is removed and the vertical christmas tree is installed, until intervention of the well is required at which time the vertical tree
10 is removed and the BOP is reinstalled. In instances when a horizontal christmas tree will be used, a BOP is installed for the drilling stage of the well. Thereafter, the BOP is removed and the horizontal christmas tree is installed with the BOP on top of it. The well is then completed and tested with the BOP installed on top of the horizontal tree. Further intervention is also conducted through the BOP on top of the horizontal tree. In any of the cases when the well is
15 being drilled, completed, or tested, a temporary landing string may be deployed within the marine riser and within the BOP.

It is important to control and monitor temperature at the BOP as well as along the marine riser. Unacceptably high temperatures could compromise the safety systems of the BOP or landing string. Unacceptably low temperatures could provide an indication of hydrate formation
20 or increased likelihood of wax deposition. Prior art systems used to obtain this information

involve running separate pods and electrical lines to obtain a single point of measurement. These prior art techniques are not capable of providing temperature measurements at multiple points along the BOP and/or marine riser.

~~For example, when produced, hydrocarbons tend to have a high temperature. On the~~

5 other hand, the marine riser, since it is surrounded by ocean water, tends to have a low temperature. Due to this temperature difference as well as the presence of other variables, hydrates sometimes form within the marine riser. The formation of hydrates in the marine riser in turn may cause blockage of flow and hold-up of intervention equipment, which could lead to a significant loss of money and time and may compromise safety systems. The ability to monitor
10 the temperature at various points along the marine riser would provide an operator the ability to predict and avoid, through appropriate chemical injection for example, the formation of hydrates within the marine riser. Moreover, the ability to monitor temperature at various points along the marine riser would also provide an operator the ability to determine the position and extent of any hydrate blockage, which would enable the operator to educatedly establish a course of
15 action.

Thus, there exists a continuing need for an arrangement and/or technique that addresses one or more of the problems that are stated above.

SUMMARY

According to a first aspect, the present invention consists of a system for measuring a
20 parameter in a subsea well, comprising: a riser extending from a platform adjacent the ocean surface towards the ocean bottom; a landing string extending within the riser from the platform towards the ocean bottom; and a line extending along at least part of the length of the landing

string and including a distributed sensor system for sensing the parameter at various points along the length of the landing string.

The invention further provides that the landing string extends at least partially within a pressure control equipment at the ocean bottom and the line can extend at least partially within
5 the pressure control equipment.

The invention further provides that the line can comprise a fiber optic line.

The invention further provides that the parameter measured can be temperature.

The invention further provides that the distributed sensor system can comprise a plurality of sensors distributed along the length of the line.

10 The invention further provides that the temperature sensors can comprise fiber optic temperature sensors.

The invention further provides that the distributed sensor system can comprise a fiber optic line, wherein light is transmitted through the fiber optic line and the returned back-scattered light is measured to provide a complete temperature profile along the length of the fiber line.

15 The invention further provides that the line can be mechanically attached to the landing string.

The invention further provides that a conduit can be located proximate the landing string; and that the fiber optic line can be located within the conduit.

The invention further provides that the conduit can be within a control umbilical
20 deployed as part of the landing string.

The invention further provides that the conduit can be one of either a hydraulic control conduit or chemical injection line that comprise the control umbilical.

The invention further provides that the conduit can be a conduit specifically deployed to house the fiber optic line.

The invention further provides that the fiber optic line can be deployed by pumping the fiber optic line through the conduit by way of fluid drag.

5 The invention further provides that the conduit can include a surface return line.

The invention further provides that the line can be located interior to the marine riser.

The invention further provides that the line can be located exterior to the marine riser.

The invention further provides that the landing string is landed on a landing shoulder located on a pressure control equipment; and that the line can extend below the landing shoulder.

10 The invention further provides that the landing string can include a passageway having a port above the landing shoulder and a port below the landing shoulder, each port providing communication to the exterior of the landing string; and that the line can be extended below the landing shoulder by passing the line through the passageway and the ports past the landing shoulder.

15 The invention further provides that the line can be a fiber optic line; and that a conduit can be located proximate the landing string and can be aligned with the passageway port located above the landing shoulder; and that the fiber optic line can be located within the conduit and can be extended below the landing shoulder by passing the line through the passageway and the ports past the landing shoulder.

20 The invention further provides that the fiber optic line can be deployed by pumping the fiber optic line through the conduit and passageway.

The invention further provides that a second conduit can be aligned with the passageway port located below the landing shoulder; and that the fiber optic line can be located within the

conduit, extended below the landing shoulder by passing the line through the passageway and the ports past the landing shoulder, and extended within the second conduit; and that the fiber optic line can be deployed by pumping the fiber optic line through the conduit, passageway, and second conduit.

5 The invention further provides that the line can be a communications line transmitting information.

 The invention further provides that the information can be transmitted between the platform and a component located below the ocean surface.

 The invention further provides that the information transmitted can be a command
10 directed at the component.

 The invention further provides that a permanent completion can be attached below the landing string.

 The invention further provides that the line can extend along at least part of a length of the permanent completion.

15 The invention further provides that the line can be monitored during deployment of the landing string and the permanent completion to determine whether the functionality of the line is compromised during deployment.

 According to a second aspect, the present invention consists of a method for measuring a parameter in a subsea well, comprising: deploying a landing string within a riser, the landing
20 string and riser extending from a platform on the ocean surface towards the ocean bottom; deploying a line along at least part of the length of the landing string, the line including a distributed sensor system for sensing the parameter at various points along the length of the

landing string ; and measuring the parameter at the various measurement points along the length of the landing string.

The invention further provides that the line can comprise a fiber optic line.

~~The invention further provides that the measuring step can comprise measuring~~

5 temperature at the various measurement points along the length of the landing string.

The invention further provides that the line can comprise a fiber optic line and the measuring step can comprise transmitting light through the fiber optic line and analyzing the returned back-scattered light to provide a complete temperature profile along the length of the fiber line.

10 The invention further provides that the deploying the line step can comprise mechanically attaching the line to the landing string.

The invention further provides that the deploying the line step can comprise disposing the line within a conduit located proximate the landing string.

The invention further provides that the disposing step can comprise disposing the line
15 within a conduit included in a control umbilical that is part of the landing string.

The invention further provides that the deploying the line step can comprise pumping the fiber optic line through the conduit by way of fluid drag.

The invention further provides that the deploying the landing string step can comprise
landing out the landing string from a landing shoulder located on a pressure control equipment;
20 and that the deploying the line step comprises extending the line below the landing shoulder.

The invention further provides that the deploying the line step can comprises deploying the line at least partially within the pressure control equipment.

The invention further provides that the deploying the line step comprises deploying the line internally to the marine riser.

The invention further provides that the deploying the line step comprises deploying the line externally to the marine riser.

5 The invention further provides attaching a permanent completion below the landing string.

The invention further provides deploying the line along at least part of a length of the permanent completion.

10 The invention further provides monitoring the parameters measured by the line during deployment to determine whether the functionality of the line is compromised during deployment.

According to a third aspect, the present invention consists of a method for monitoring hydrates in a subsea well, comprising: deploying a landing string within a riser, the landing string and riser extending from a platform on the ocean surface towards the ocean bottom;
15 deploying a fiber optic line along at least part of the length of the landing string, the line including a distributed temperature sensor system for sensing the temperature at various points along the length of the landing string; measuring the temperature at the various measurement points along the length of the landing string; and determining the presence of hydrates within the marine riser or landing string by analyzing the temperature measurements.

20 The invention further provides that the determining step can further comprise determining the location of the hydrates by analyzing the temperature measurements.

The invention further provides that the determining step can further comprises determining the effect of treatment conducted on the hydrates by analyzing the temperature measurements.

~~The invention further provides that the deploying a fiber-optic line step can comprise~~

5 pumping the line through a conduit located proximate the landing string by way of fluid drag.

Advantages and other features of the invention will become apparent from the following description, drawing and claims.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a schematic of a subsea well.

10 Fig. 2 is an elevational view of the connection between the landing string and the tubing hanger assembly, with the landing string having a line that includes a distributed sensor system.

Fig. 3 is one technique used to deploy the distributed sensor system.

Fig. 4 is another technique used to deploy the distributed sensor system.

15 Fig. 5 is an elevational view showing the use and deployment of the present invention within and through a horizontal christmas tree.

Fig. 6 shows a schematic of the technique used to enables the deployment of the distributed sensor system past the landing shoulder of a wellhead.

Fig. 7 shows the part of the landing string that enables the deployment of the distributed sensor system past the landing shoulder of a wellhead.

20 Fig. 8 shows the line deployed exterior to the marine riser.

Fig. 9 shows the line deployed with a permanent completion.

DETAILED DESCRIPTION

Figure 1 shows the case of a subsea well 10 that will include a vertical christmas tree, and Figure 5 shows the case of a subsea well that includes a horizontal tree. The use of a BOP in relation to a vertical or horizontal christmas tree was previously generally described herein. For purposes of clarity, blow out preventers and christmas trees will generally be referred to as “pressure control equipment.” Whether a vertical or horizontal christmas tree is used is not of primary concern for this invention.

Turning to Figure 1, the subsea well 10 includes a platform 12, a marine riser 14, a blow out preventer (BOP) 16, and a landing string 18. The platform 12, which can be a floating platform or vessel, is typically located on the ocean surface 20, and the BOP 16 is located on the ocean floor 22. The marine riser 14 extends from the platform 12 to the BOP 16. The landing string 18 extends within the marine riser 14 from the platform 12 to the BOP 16. The wellbore 24, which is in fluid communication with the interior of the BOP 16, intersects a formation 26. Wellbore 24 may be cased or uncased. A major string 19 may be attached to the landing string 18 and may extend below the BOP 16 and into the wellbore 24.

When landing string 18 is utilized to test formation 26 and the major string 19 extends below the wellhead, the major string 19 may include a packer 30 that is selectively sealable against the wellbore 24 wall located and that is located above an inlet section 28. Inlet section 28 provides fluid communication between the formation 26 and the interior of the landing string 18. When an operator is ready to test wellbore 24, hydrocarbons are induced to flow from the formation 26, into the wellbore 24 (through perforations in the casing if the wellbore 24 is cased), through the inlet section 28, through the BOP 16, and up to the platform 12 through the landing string 18.

The use of landing string 18 and major string 19 in order to facilitate testing formation 26 is described for exemplary purposes only. As previously disclosed, other configurations of landing string 18 may be used for drilling wellbore 24, completing the wellbore (as shown in Figure 9), and other workover operations. In the testing configuration, the components for

5 landing string 18 would change depending on its use. The landing string 18 area proximate the BOP 16 as well as any associated equipment is commonly referred to as the "subsea test tree."

Figure 2 is a detailed view of the landing string 18 and BOP 16. The landing string 18 is landed on a hanger or upper casing hanger, generically described as hanger 25, located at the bottom of the wellhead. The landing profile 27 on landing string 18 is at least partially supported
10 by hanger 25. BOP 16 includes a plurality of ram sets 17 that are extendable from a retracted position that enables the passage of the landing string 18 to a contracted position that engages (and depending on the ram set seals) against the landing string 18. For instance, ram sets 17a, 17b, and 17c are shown in their retracted position, whereas ram set 17d is shown in its contracted position.

15 Above the BOP 16, landing string 18 may include at least one and typically two barrier valves 13, such as ball, flapper, or disc valves. Moreover, above the BOP 16, landing string 18 may also include additional equipment 15, as necessary to complete the objective of the drilling, testing, completion, or workover operation. Such equipment may include additional packers, telemetry or control modules, motors, pumps, or valves to name a few.

20 Within the BOP 16, landing string 18 may also include at least one and typically two barrier valves 29, such as ball, flapper, or disc valves, which provide additional necessary safety mechanisms for well shut-in and control. Within the BOP 16, landing string 18 may also include an unlatching mechanism 31 and a retainer valve 33. Unlatching mechanism 31 separates the

section of the landing string 18 therebelow from the section of the landing string 18 thereabove to allow string disconnect and removal or displacement of the platform from above the BOP and wellhead. Retention valve 33 is a valve which, if the landing string 18 is separated as described in the previous sentence, prevents any fluid located in the section of the landing string 18 above retention valve 33 from venting into the ocean or marine riser 14.

As can be seen in Figure 2, a line 34 can be deployed in the riser annulus 32 between the landing string 18 and the marine riser 14. In another embodiment as shown in Figure 8, the line 34 can be deployed exterior or interior and attached to the marine riser 14. The line 34 includes a distributed sensor system 37. The distributed sensor system 37 includes measurement points 35 distributed along its length, each measurement point measuring a parameter such as temperature, pressure, strain, acoustic vibrations, or chemical species. It is understood that reference number 35 is shown only for purposes of illustration and exemplary location. The measurement points 35 may be dispersed along line 34 as required by the user to provide the desired resolution.

Line 34 may be attached to equipment 36, which equipment receives, analyzes, and interprets the readings received from the measurement points 35. Equipment 36 may be located at the ocean surface 20 or at the ocean floor 22, among other places.

In one embodiment, line 34 is a fiber optic line, and the surface equipment 36 comprises a light source and a computer or logic device for obtaining, interpreting, and analyzing the measurement point 35 readings. The measurement points 35 and fiber optic line 34 in one embodiment may be configured to measure temperature at each point 35. Generally, in one embodiment, pulses of light at a fixed wavelength are transmitted from the light source in surface equipment 36 down the fiber optic line 34. At every measurement point 35 in the line 34, light is

back-scattered and returns to the surface equipment 36. Knowing the speed of light and the moment of arrival of the return signal, enables its point of origin along the fiber line 34 to be determined. Temperature stimulates the energy levels of the silica molecules in the fiber line 34.

The back-scattered light contains upshifted and downshifted wavebands (such as the Stokes

5 Raman and Anti-Stokes Raman portions of the back-scattered spectrum) which can be analyzed to determine the temperature at origin. In this way the temperature of each of the responding measurement points 35 in the fiber line 34 can be calculated by the equipment 36, providing a complete temperature profile along the length of the fiber line 34. This general fiber optic distributed temperature system and technique is known in the prior art. As further known in the
10 art, it should be noted that the fiber optic line 34 may also have a surface return line so that the entire line has a U-shape. One of the benefits of the return line is that it may provide enhanced performance and increased spatial resolution to the temperature sensor system.

In another embodiment, distributed sensor system 37 may include a fiber optic sensor located at each measurement point 35 along the line 24. For instance, each fiber optic sensor
15 may comprise a brag grating temperature sensor that reflects light back to the equipment 36. As is known in the art, the light reflected by the brag grating temperature sensors 35 can be dependent on the temperature of the environment. Thus, the equipment 36 analyzes this dependency and calculates the temperature at the particular sensor 35. Other types of fiber optic sensors that can be distributed along a fiber optic line 34 may also be used.

20 In another embodiment, the line 34 is an electrically conductive line, and the sensors are electrically powered. Equipment 36, for an electrically conductive line 34, may comprise a power source and a computer for reading the measurements. In yet another embodiment, the line

34 is a hybrid fiber optic and electrically conductive line, wherein the optical fiber may be disposed within the electrically conductive line.

Installation of line 34 can be performed using a variety of techniques and methods. As shown in Figure 3, the line 34 can be mechanically attached, such as by fasteners 38, to the landing string 18 and thereby deployed along with the landing string 18. This installation technique may also be used in the embodiment shown in Figure 8 with the fasteners attaching the line 34 to the exterior of the marine riser 14. The line 34 may also be attached to the interior of the marine riser 14.

Another deployment technique which is particularly useful for a fiber optic line 34 is to pump the fiber optic line 34 down a conduit, such as conduit 40 shown in Figure 4. This technique is described in United States Reissue Patent 37,283. Essentially, the fiber optic line 34 is dragged along the conduit 40 by the injection of a fluid at the surface. The fluid and induced injection pressure work to drag the fiber optic line 34 along the conduit 40. It is noted that although the conduit 40 is shown mechanically attached to the landing string 18 by way of fasteners 42, the conduit 40 may instead be attached to the interior of the landing string 18 or to the exterior or interior of riser 14. This pumping technique may also be used in configurations where a surface return line provides the U-shape previously discussed. This installation technique may also be used in the embodiment shown in Figure 8 wherein the conduit 40 would be attached to the exterior of the marine riser 14.

In one embodiment, conduit 40 may comprise a conduit that is deployed specifically for use as a fiber optic deployment conduit. In another embodiment, conduit 40 may comprise a conduit already existing on the landing string 18, such as a hydraulic conduit utilized to control other equipment or a chemical injection line used to inject chemicals into desired locations at

desired times. Both hydraulic conduits and chemical injection lines can be found within control umbilicals. Figure 5 shows a landing string 18 having a control line umbilical 51 that includes a plurality of control lines 53, such as hydraulic conduits and chemical injection lines. Fiber optic line 34 may be deployed through any of the control lines 53 by use of the fluid drag technique

5 previously described.

In one embodiment, line 34 is pumped into conduit 40 prior to deployment of the landing string 18 and the conduit 40 is then attached (with line 34 therein) to the landing string 18. In another embodiment, the line 34 is also located within a conduit 40 that is attached to either the landing string 18 or riser 40, but the line 34 is manually inserted within the conduit 40 as the
10 landing string 18 is deployed.

In one embodiment as shown in Figure 2, the line 34 extends to the BOP 16 and then either terminates or returns to the surface (U-shape) prior to the hanger 25. In another embodiment as illustrated in Figures 6-7, the line 34 is continued through the BOP 16 below the hanger 25 and down to a selected point on the major string 19 located within wellbore 24 (the
15 line 34 may return to the surface in the U-shape from this point as well). Obtaining measurement points below the hanger 25 can be beneficial for the reasons previously indicated in relation to measurement points above the hanger. As subsea wells become more prevalent and get deeper and deeper, operators will desire as much information as possible from these high value and risk investments. Presently, subsea wells have less productivity than comparable land wells primarily
20 due to the relative lack of data available on the subsea wells.

Line 34 can be extended below the hanger 25 and across rams 17 by passing the line 34 through a passageway located within the landing string 18 / major string 19, as generally shown in Figure 6. Thus, since the line 34 passes within the landing string 18 at the general location

where the landing string 18 is landed on the hanger 25 (and is proximate the rams 17), the connection between the landing string 18 and the hanger 25 or rams 17 does not affect the line 34 or its performance. Figure 7 illustrates a part 59 of the landing string 18 that can be used to extend the line 34 below the hanger 25 and past the rams 17 in this manner. Figure 7 shows the part 59 of the landing string 18 that includes landing profile 27. Part 59 also includes a passageway 60. Passageway has a port 62 above the landing profile 27 providing fluid communication to the exterior of the landing string 18 and a port 64 (not shown in Figure 7 but similar to port 62) below the landing profile 27 providing fluid communication to the exterior of major string 19. The line 34 can be extended through passageway 60 from port 62 to and through port 64 without being harmed or affected by the connection between hanger 25 or rams 17 and landing string 18. Use of pressure fittings at the ports may be required. Thus, the same line 34 can be used to measure the temperature above and below the ocean floor 22. It is noted that the deployment technique with conduit 40 (utilizing fluid drag) can also be used when the line 34 extends below the hanger 25 by aligning the conduit 40 with port 62 and, if desired, by adding a similar conduit from port 64 to the desired location.

Although part 59 is shown as being constructed from an integral piece, part 59 can be constructed from a plurality of sections having aligned passageways enabling the passage of line 34 past the hanger 25. It is further noted that pieces similar to part 59 (that include passageways 60) with appropriate fluid communication and porting, may have to be used above hanger 25 in order to pass the line 34 past any contracted rams 17a-17d. Similar porting may also have to be used in tools 29, 31, and 33.

Turning to Figure 5, the subsea well 10 shown therein includes a horizontal christmas tree 70. As previously disclosed, BOP 16 is typically removably attached to the top of the

horizontal christmas tree 70. Like numerals between the Figures 1 and 5 represent like parts.

All aspects of the present invention may be used in and deployed through a horizontal christmas tree 70. The main difference between the deployment of Figure 1 and that of Figure 5 is that if a

~~horizontal christmas tree 70 is used, the landing profile 27 of the landing string 18 lands on the~~

5 tubing hanger 25' of the tree 70. Once an operator is prepared, production may be continued or commenced through the flow lines 72 of the horizontal tree 70. For purposes of clarity, the hanger 25 and the tubing hanger 25' will generally be referred to as a "landing shoulder."

With the line 34 configured and deployed as previously described, the distributed sensor system 37 and surface equipment 36 are utilized to provide measurements, such as for

10 temperature, at the various measurement points 35 along the landing string 18, which measurement points 35 may also be extended below the ocean floor 22 and past the landing shoulder if the line extension as discussed above is also used. With these measurements, an operator is able to determine whether the temperature within the BOP 16 and the marine riser 14 is outside the acceptable range. Moreover, these temperature measurements enable an operator

15 to predict and model hydrate formation and other chemical depositions (wax, scale, etc.) and thus take measures to prevent these formations, such as by the appropriate chemical injection. With the temperature measurements at the BOP, an operator also knows the temperature of the effluents flowing out of the well which enables the operator to purchase the appropriate wellhead and subsea equipment for production, including procuring and specifying rams that are designed

20 to provide a seal at high temperatures and pipeline systems that provide the required degree of thermal insulation. In addition, any permanent riser or production umbilical installed for the production phase must be rated to ensure structural integrity in the face of the currents, which can sway or vibrate or move such equipment. The temperature measurements provided by this

invention can provide qualitative information on ocean currents that are a critical consideration in production and drilling riser design.

The invention as disclosed may also be used to monitor the presence and removal of hydrates once they are formed in either the marine riser 14 or within the wellbore 24. As is known, hydrates have a temperature that is substantially lower than the temperature of the flowing hydrocarbons. This temperature difference, and thus the formed hydrates, can easily be located and sensed by the distributed sensor system 37. This information, particularly the location, extent, and length of the blockage, enables an operator to choose the appropriate treatment method. During treatment, the same distributed sensor system 37 provides the ability to monitor the effect of the chosen treatment method. The monitoring of the presence and removal of hydrates can be conducted whether or not the particular landing string involved already includes an installed line 34. If the relevant landing string already does have an installed line, then the same line can be used to provide the monitoring. If the relevant landing string does not already have an installed line, then a line 34 can be deployed through one of the control lines 53 of the control line umbilical 51 (such as by use of the fluid drag method previously discussed).

In any of the embodiments previously described, line 34 may also be used as a communications line between the surface and the subsea environment. For instance, line 34 may be operatively linked to a valve, such as a barrier valve 13, a barrier valve 29, or a retainer valve 33, to communicate the position of such valve to the surface. Line 34 may also communicate the status of or information/data from other components, such as packers, perforating guns, or sensors, even if such components are located within wellbore 24. Moreover, a command may be

sent through the communications line in order to trigger the activation of one of the downhole components.

Much of the disclosure thus far has dealt with the exploration and appraisal phases of a subsea well. However, this invention may also be used in conjunction with a subsea well

5 permanent completion, including during its installation. In Figure 9, a permanent completion 100 is shown being deployed in subsea well 99. As in the prior figures and disclosure, the permanent completion 100 is deployed in a wellbore 102 and through a marine riser 104 and BOP 106. The permanent completion 100 is suspended from a landing string 108. A tubing hanger 110 and tubing hanger running tool 112 are disposed between the landing string 104 and
10 permanent completion 100. When the permanent completion 100 is fully deployed within the wellbore 102, tubing hanger 110 hangs from wellhead 114 and suspends the tubing hanger 110 therefrom. As is known, once the operator is ready, the tubing hanger running tool 112 is disconnected and the landing string 108 and tubing hanger running tool 112 are retrieved.

Also as in the prior figures and disclosures, a line 116 (like line 34) can be deployed
15 alongside the landing string 108 and permanent completion 100. The line 116 may be deployed within a conduit 118, such as manually or by fluid drag, as previously disclosed. The tubing hanger 110 and tubing hanger running tool 112 have ports 120 and passageways 122 to allow the passage of the line 116 therethrough, specially when the tubing hanger 110 is landed on the wellhead 114. The ports 120 and passageways 122 are similar to the ports 62 and passages 60 of
20 Figure 7 and for fiber optic lines may include optical wet connects in order to provide optical communication therethrough (in which case the line 116 may not be able to be pumped in by fluid drag). When the line 116 is deployed alongside the permanent completion 100, the line 116

is typically meant to be permanently installed in the wellbore 102 with the permanent completion 100.

As the permanent completion 100 is deployed through the marine riser 104 and BOP 106 and then into the wellbore 102, there is a risk that the line 116 and conduit 118 will be damaged thus compromising the functionality thereof. This risk is specially high in horizontal wells. In order to monitor this potential damage, the line 116 is attached to equipment 122 during the deployment of the landing string 108 and permanent completion 100. The equipment receives, analyzes, and interprets the readings received from the measurement points along the line 116. As long as the equipment 122 continues receiving data from all of the measurement points along the line 116 or as long as such data is within an expected and/or acceptable range, an operator can be more certain that the line 116 and conduit 118 have not been damaged. However, if the equipment 122 stops receiving data from at least one of the measurement points or the data received is not within the expected and/or acceptable range, this may indicate that the line 116 and conduit 118 have been damaged. Since the operator will be able to determine whether damage has occurred during the deployment, the operator will have the choice of stopping deployment operation and retrieving the landing string 108 and permanent completion 100 to fix the damage. Otherwise, the operator would have to wait until the permanent completion 100 is fully deployed and installed in the wellbore 102 to determine if there is damage, at which time retrieval and repair are much more costly.

While the invention has been disclosed with respect to a limited number of embodiments, those skilled in the art, having the benefit of this disclosure, will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of the invention.

What is claimed is:

1. A system for measuring a parameter in a subsea well, comprising:

a riser extending from a platform adjacent the ocean surface towards the ocean bottom;

a landing string extending within the riser from the platform towards the ocean bottom;

and

5 a line extending along at least part of a length of the landing string and including a distributed sensor system for sensing the parameter at various points along the length of the landing string.

2. The system of claim 1, wherein:

the landing string extends at least partially within a pressure control equipment at the

10 ocean bottom; and

the line extends at least partially within the pressure control equipment.

3. The system of claim 1, wherein the line comprises a fiber optic line.

4. The system of claim 1, wherein the parameter measured is temperature.

15

5. The system of claim 4, wherein the distributed sensor system comprises a plurality of sensors distributed along the length of the line.

6. The system of claim 5, wherein the temperature sensors comprise fiber optic temperature sensors.

7. The system of claim 4, wherein the distributed sensor system comprises a fiber optic line and wherein light is transmitted through the fiber optic line and the returned back-scattered light is measured to provide a complete temperature profile along the length of the fiber line.

8. The system of claim 1, wherein the line is mechanically attached to the landing string.

9. The system of claim 3, further comprising:
a conduit located proximate the landing string; and
the fiber optic line located within the conduit.

10. The system of claim 9, wherein the conduit is within a control umbilical deployed as part of the landing string.

11. The system of claim 10, wherein the conduit is one of either a hydraulic control conduit or chemical injection line that comprise the control umbilical.

12. The system of claim 9, wherein the conduit is a conduit specifically deployed to house the fiber optic line.

13. The system of claim 9, wherein the fiber optic line is deployed by pumping the fiber optic line through the conduit by way of fluid drag.

~~14. The system of claim 9, wherein the conduit includes a surface return line.~~

5 15. The system of claim 1, wherein the line is located interior to the marine riser.

16. The system of claim 1, wherein the line is located exterior to the marine riser.

17. The system of claim 1, wherein:

the landing string is landed on a landing shoulder located on a pressure control

10 equipment; and

the line extends below the landing shoulder.

18. The system of claim 17, wherein:

the landing string includes a passageway having a port above the landing shoulder and a port below the landing shoulder, each port providing communication to the exterior of the

15 landing string; and

the line is extended below the landing shoulder by passing the line through the passageway and the ports past the landing shoulder.

19. The system of claim 18, wherein:

the line is a fiber optic line;

a conduit is located proximate the landing string and is aligned with the passageway port located above the landing shoulder; and

5 the fiber optic line is located within the conduit and is extended below the landing shoulder by passing the line through the passageway and the ports past the landing shoulder.

20. The system of claim 19, wherein the fiber optic line is deployed by pumping the fiber optic line through the conduit and passageway.

10

21. The system of claim 20, wherein:

a second conduit is aligned with the passageway port located below the landing shoulder;

the fiber optic line is located within the conduit, is extended below the landing shoulder by passing the line through the passageway and the ports past the landing shoulder, and extends

15 within the second conduit; and

the fiber optic line is deployed by pumping the fiber optic line through the conduit, passageway, and second conduit.

22. The system of claim 1, wherein the line is a communications line transmitting information.

20

23. The system of claim 22, wherein the information transmitted is between the platform and a component located below the ocean surface.

24. The system of claim 22, wherein the information transmitted is a command directed at the component.

~~25. The system of claim 1, further comprising a permanent completion attached~~

5 below the landing string.

26. The system of claim 25, wherein the line extends along at least part of a length of the permanent completion.

10 27. The system of claim 26, wherein the line is monitored during deployment of the landing string and the permanent completion to determine whether the functionality of the line is compromised during deployment.

28. A method for measuring a parameter in a subsea well, comprising:
15 deploying a landing string within a riser, the landing string and riser extending from a platform on the ocean surface towards the ocean bottom;

deploying a line along at least part of a length of the landing string, the line including a distributed sensor system for sensing the parameter at various points along the length of the landing string ; and

20 measuring the parameter at the various measurement points along the length of the landing string.

29. The method of claim 28, wherein the line comprises a fiber optic line.

30. . . The method of claim 28, wherein the measuring step comprises measuring temperature at the various measurement points along the length of the landing string.

5 31. The method of claim 30, wherein the line comprises a fiber optic line and the measuring step comprises transmitting light through the fiber optic line and analyzing the returned back-scattered light to provide a complete temperature profile along the length of the fiber line.

10 32. The method of claim 28, wherein the deploying the line step comprises mechanically attaching the line to the landing string.

33. The method of claim 28, wherein the deploying the line step comprises disposing the line within a conduit located proximate the landing string.

34. The method of claim 33, wherein the disposing step comprises disposing the line within a conduit included in a control umbilical that is part of the landing string.

15

35. The method of claim 33, wherein the deploying the line step comprises pumping the fiber optic line through the conduit by way of fluid drag.

36. The method of claim 28, wherein:

the deploying the landing string step comprises landing out the landing string at a landing shoulder located on a pressure control equipment; and

the deploying the line step comprises extending the line below the landing shoulder.

5 37. The method of claim 28, wherein the deploying the line step comprises deploying the line at least partially within the pressure control equipment.

38. The method of claim 28, wherein the deploying the line step comprises deploying the line internally to the marine riser.

10

39. The method of claim 28, wherein the deploying the line step comprises deploying the line externally to the marine riser.

40. The method of claim 22, further comprising attaching a permanent completion
15 below the landing string.

41. The method of claim 40, further comprising deploying the line along at least part of a length of the permanent completion.

20 42. The method of claim 41, further comprising monitoring the parameters measured by the line during deployment to determine whether the functionality of the line is compromised during deployment.

43. A method for monitoring hydrates in a subsea well, comprising:

deploying a landing string within a riser, the landing string and riser extending from a platform on the ocean surface towards the ocean bottom;

5 deploying a fiber optic line along at least part of the length of the landing string, the line including a distributed temperature sensor system for sensing the temperature at various points along the length of the landing string;

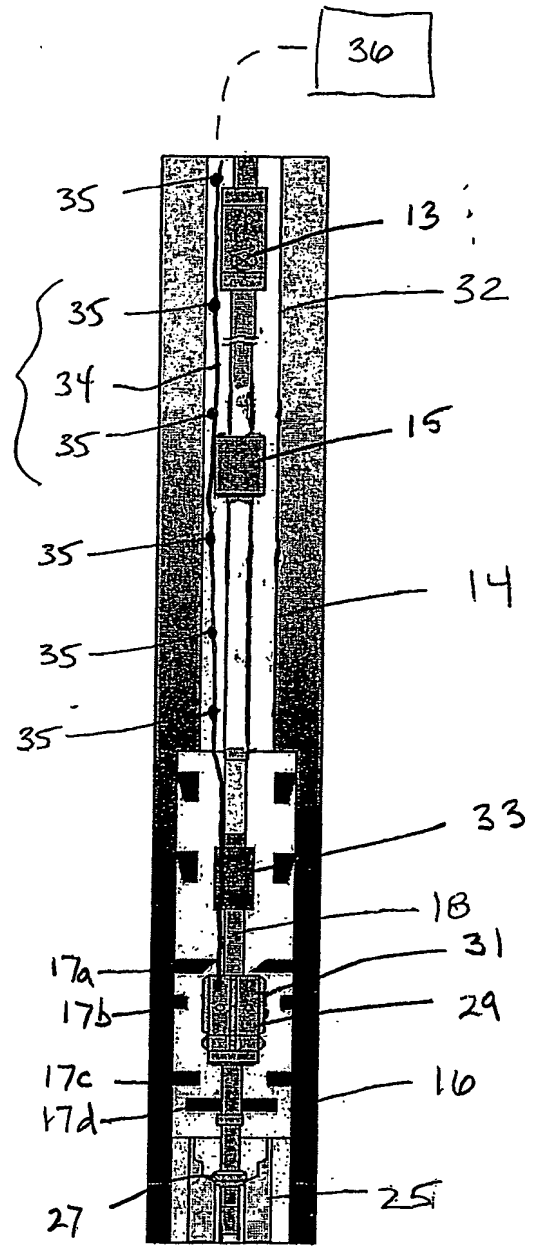
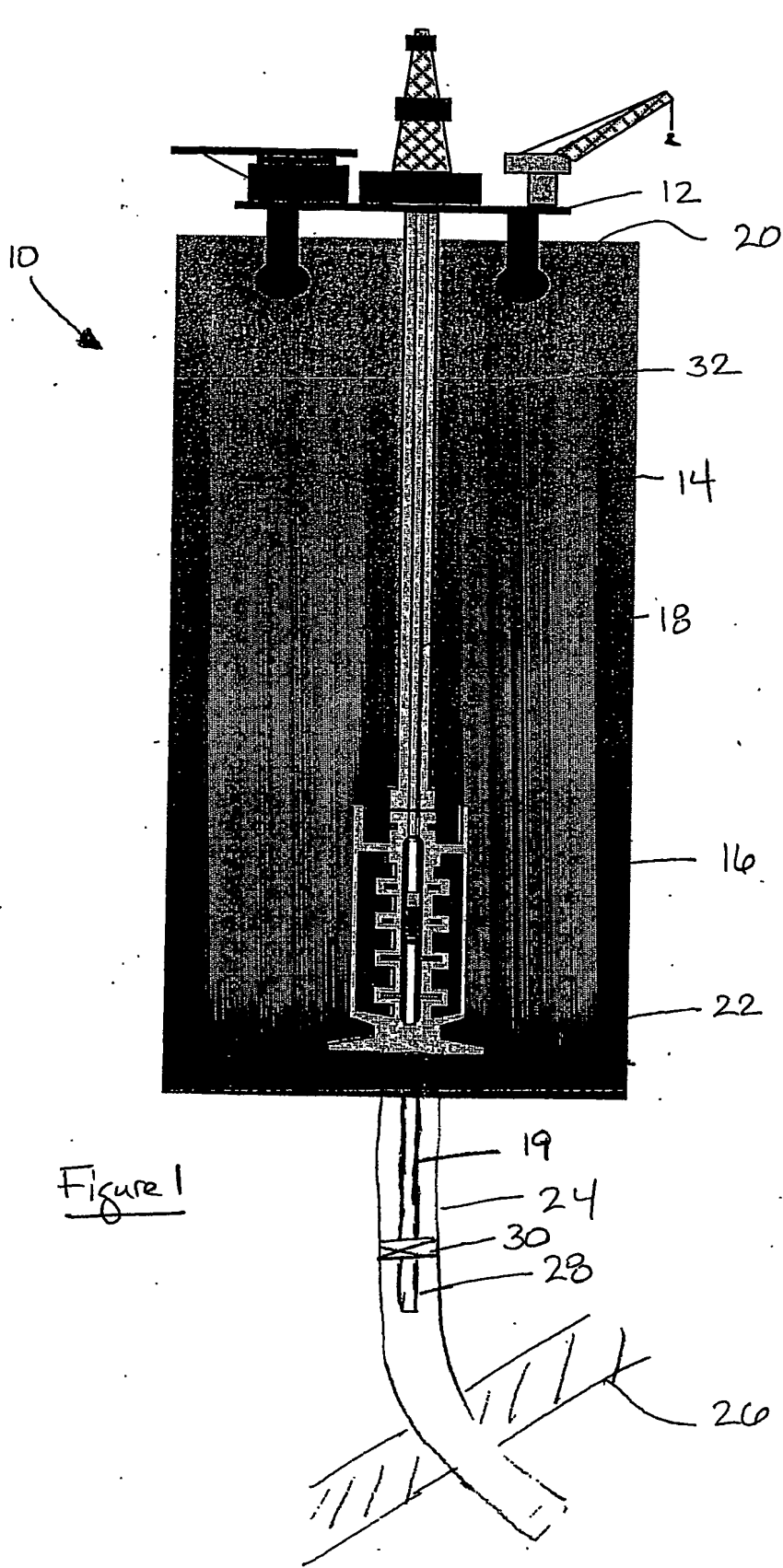
measuring the temperature at the various measurement points along the length of the landing string; and

10 determining the presence of hydrates within the marine riser or landing string by analyzing the temperature measurements.

44. The method of claim 43, wherein the determining step further comprises determining the location of the hydrates by analyzing the temperature measurements.

15 45. The method of claim 44, wherein the determining step further comprises determining the effect of treatment conducted on the hydrates by analyzing the temperature measurements.

20 46. The method of claim 43, wherein the deploying a fiber optic line comprises pumping the line through a conduit located proximate the landing string by way of fluid drag.



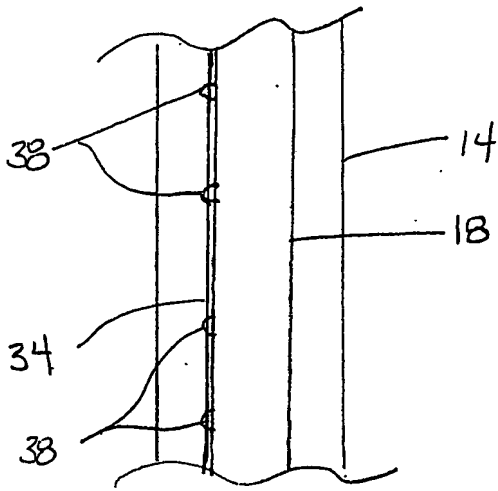


Figure 3

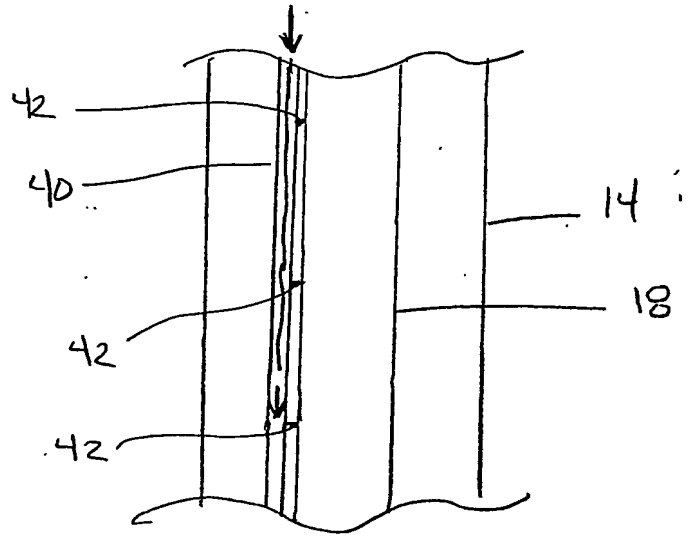


Figure 4

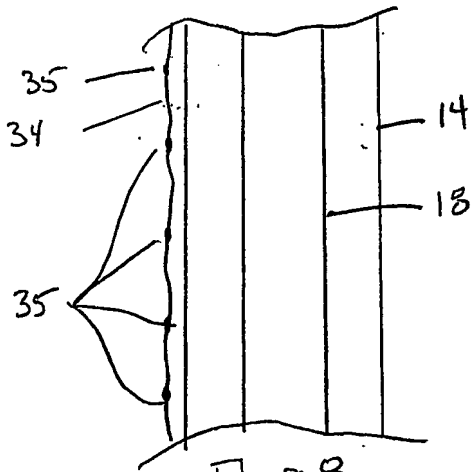


Figure 5

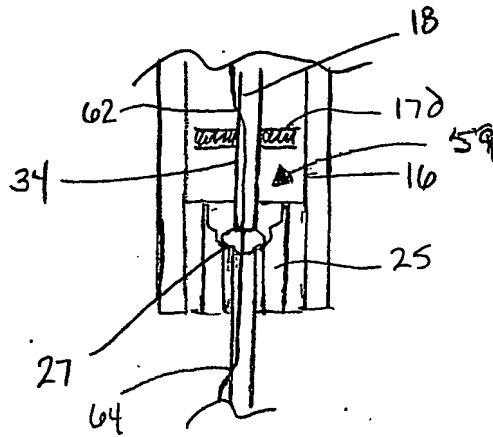


Figure 6

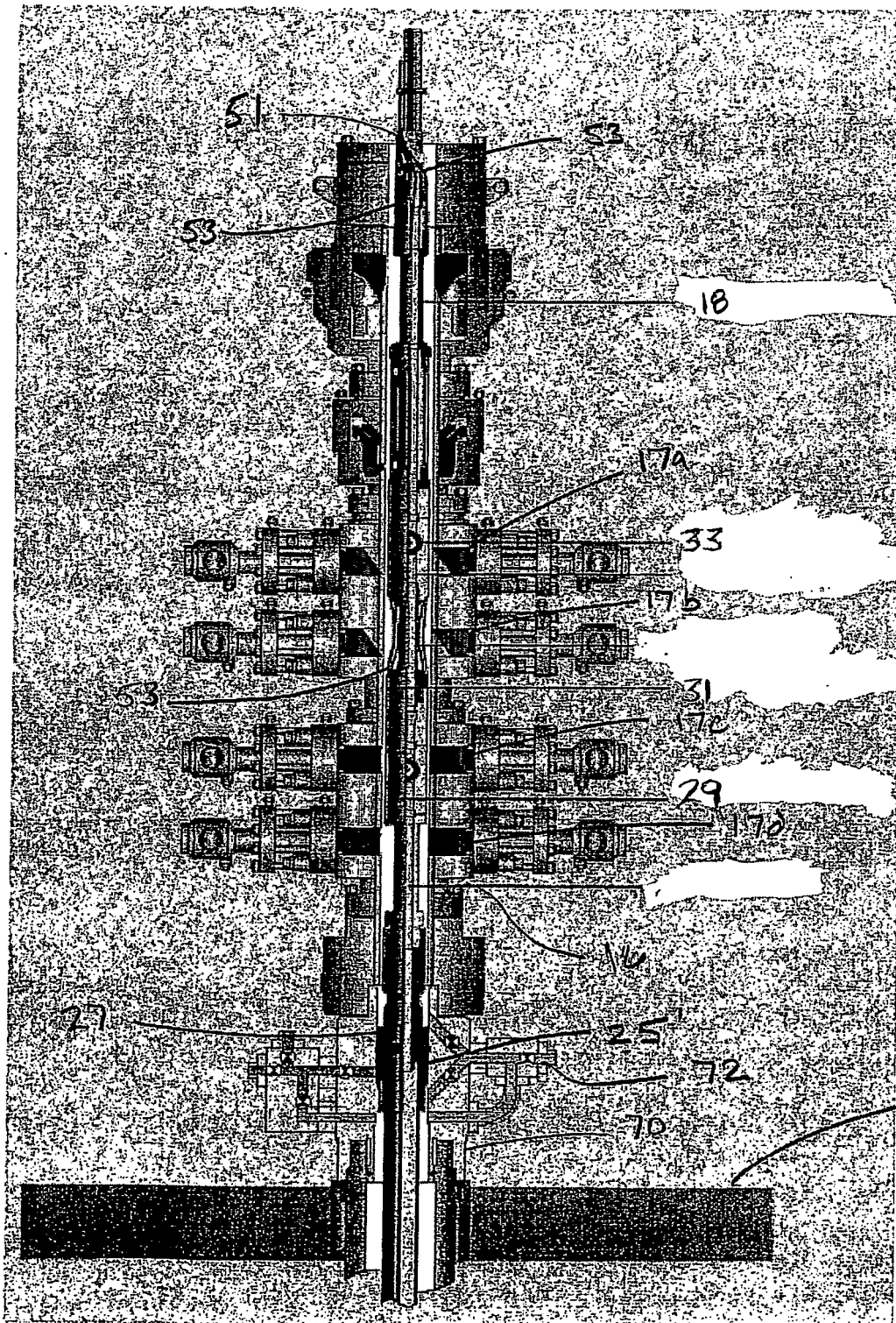
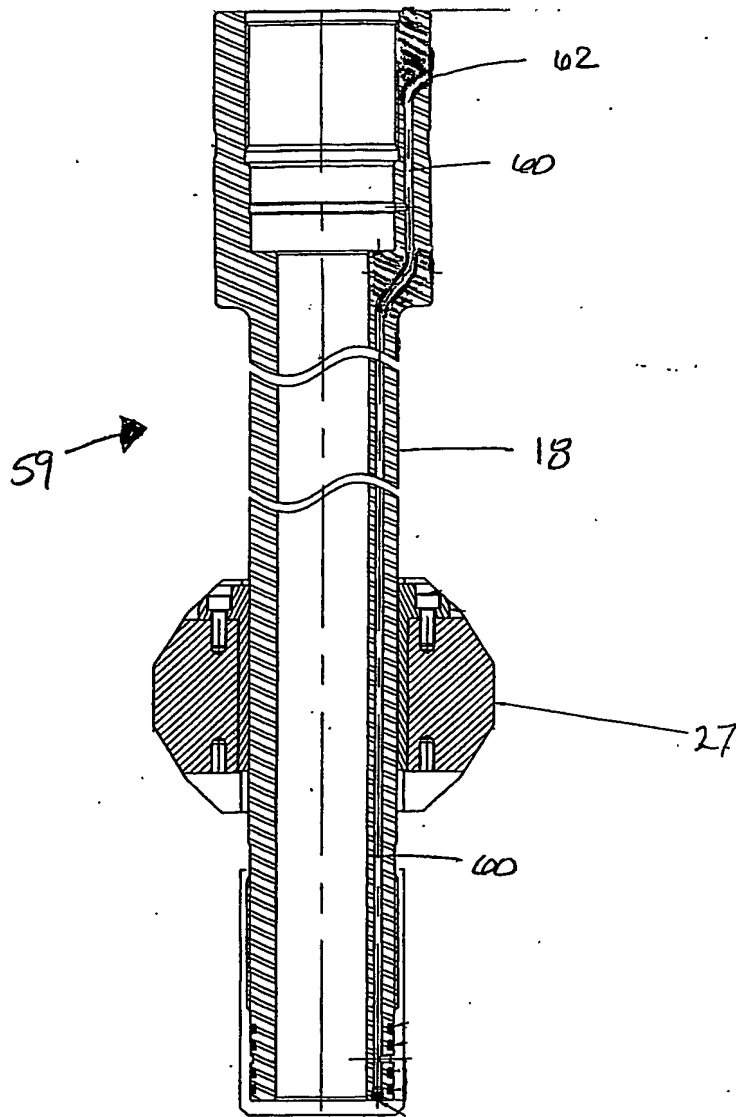
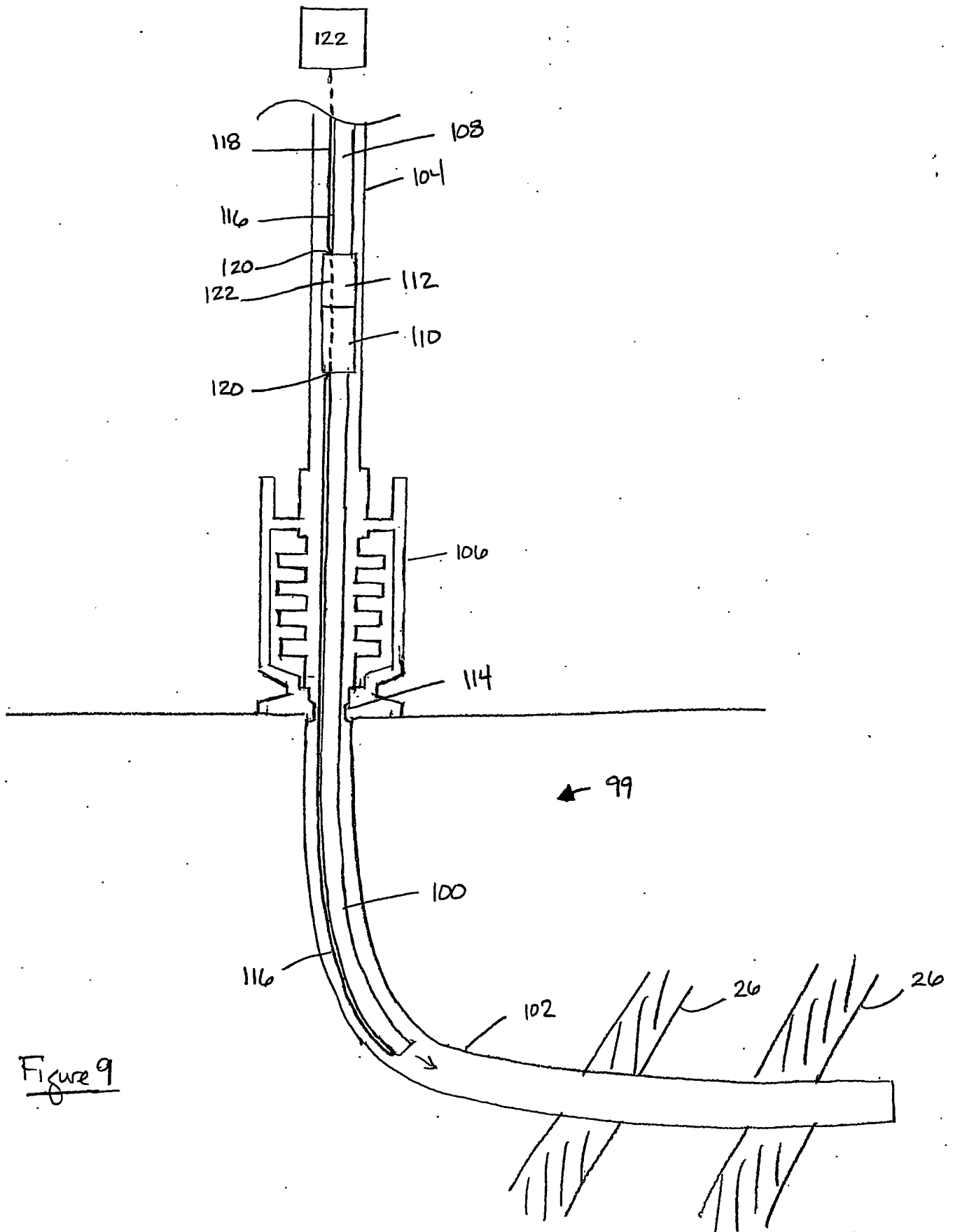


Figure 5

Figure 7





**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☒ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☒ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.